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Honors Capstone Project

Applications of Extremophiles in Martian Astrobiology

Introduction

The study of extremophiles, microorganisms that live in extreme environments, is a rapidly growing area of research. It is only recently that scientists have discovered that these types of microorganisms exist; discovering extremophile existence in locations such as toxic acid drainage sites, cold Antarctic deserts, and deep under the Earth's surface. While all extremophiles differ vastly, they are connected by one trait: their ability to thrive in environments where no other life survives, even outer space. This review will focus on current research of Martian astrobiology. Because of the characteristics many extremophiles possess, they are common model organisms for extraterrestrial life. The environments discussed in this literature review serve as terrestrial analogs for Martian environments. The most recent literature is sending extremophiles in space and simulated extraterrestrial conditions to measure survival rates. Future applications include discovering life on Mars or possibly populating others planets with life (Rampelotto).

Types of Extremophiles

It was previously thought that many areas of the earth are devoid of life. Scientists now know that to be false, due to a wide array of extremophiles that have been discovered. The literature explores extremophiles that often occupy environmental niches few organisms can live in, such as adverse temperatures, pH levels, pressure, or salt concentrations. Extremophiles can come from all three domains of life, bacteria, archaea, and eukarya, although most are archaea (Rampelotto).

Acidophiles

Acidophiles are organisms that survive in acidic environments, often at pH levels below two. Research from Bond et al. sampled acidophiles present as a slime growth in an acid mine drainage site in Iron Mountain, California. It was found that the slime growth was composed of 71% new species, and grow optimally at a pH close to 0. Many acidophiles, including the ones sampled, survive by oxidizing iron. Acidophiles are found in caves, sulfur pools, or in places where acidic pollutants exist. (Bond et al.). The research connected acidophiles to the Martian environment. Acidophiles use chemolithotrophic metabolisms, which means they obtain energy through inorganic minerals. The iron oxides and iron sulfates many acidophiles use have recently been identified on Mars in the Tinto basin. Additionally, the mineral and geological composition on Mars is similar to the caves many acidophiles inhabit on Earth (Horneck).

Psychrophiles

Psychrophiles are organisms that survive in temperatures below -15 C. Literature from Cockell and Stokes examined Arctic and Antarctic polar deserts for signs of life on exposed surface rock. The rock sampled mostly consisted of quartz. The study showed that cyanobacteria were found in 95% of the rocks sampled. The researchers deduced that cyanobacteria live under quartz to escape the wind, radiation, and cold. Since quartz is somewhat translucent, the cyanobacteria are able to generate energy using photosynthesis. Psychrophiles have also been found at deep sea, on mountains, and inside glaciers. Cold normally causes organisms to slow their rate of growth, nutrient transport, and enzyme activity. Psychrophiles are able to mitigate all of those effects to thrive in cold environments (D'Amico et al.).

Research concluded that psychrophiles are equally as applicable to terrestrial environments. Many psychrophiles deal with not only low temperature, but dry climate and enhanced UV radiation, all conditions that mimic Martian conditions. One of the largest barriers facing possible life on Mars, low temperatures at night, would allow psychrophiles to live. In addition, polar ice caps on Mars are a promising area of for life to be found, as psychrophiles has been found in similar conditions inside Earth's ice caps (Cockell and Stokes).

Radioresistant Microbes

Some extremophiles are radioresistant, that is, they can survive high amounts of radiation. An investigation from Zahradka et al. sought to explore why the extremophile *Deinococcus radiodurans* can withstand high radiation treatment. The researchers found that DNA of *D. radiodurans* is broken into thousands of pieces upon radiation, but quickly repairs itself in a two-step mechanism. Other types of radioresistant microbes have been found living in the Chernobyl nuclear reactor site. Among all types of radioresistant microbes, *D. radiodurans* is the most radiation-resistant organism to date and is said to mimic organisms that existed in early-life environments on Earth. This is important to Martian research because the atmosphere on early-life Earth is similar to current conditions on Mars, with no ozone protecting the planet from high solar UV levels. As such, *D. radiodurans* would be able to survive the intense Martian UV levels of radiation. (Horneck). When this was tested by De La Vega, U., P. Rettberg, and G. Reitz, it was found that *D. radiodurans* could survive seven days in a simulated Martian climate if radiation was present. When radiation was present, the viability of *D. radiodurans* greatly decreased. The literature concluded that *D. radiodurans* could live in a Martian environment if it was shielded by dust or soil.

Epiliths

Epilithic organisms are organisms that grow on top of rocks. Many epilithic organisms are extremophiles, although not all possess this trait. Research from Brandt et al. measured how long an extremophile lichen *Xanthoria elegans*, composed of an algae and fungal symbiotic relationship, can survive in extraterrestrial conditions. The lichen was measured for survival in space and a simulated Martian environments on the International Space station. The lichen was exposed to conditions such as vacuum atmosphere, rapid temperature cycling, and cosmic radiation over 1.5 years. It was found that the survival rate in algae was 50-80% and 60-90% in the fungal symbiont. *X. elegans* was be tested in space because of the environment it inhabits on Earth, Antarctica rocks, mimics that of a Martian environment. The literature concluded that *X. elegans* was labeled as an appropriate model organism for extended space travel and life on Mars (de Vera).

Endoliths

Endoliths are able to withstand living deep within the Earth's crust, and even solid rock. Li et al. analyzed the chemistry of water far beneath the Earth's surface and found evidence of endolith life. The literature found that the concentrations of sulfur were 100-1,000 times less than expected, leading the researchers to suspect the existence of sulfate metabolizing bacteria exist. If current research is correct, these microbes will have been separated from the surface of the Earth for 2.7 billion years. This is a notable example because these extremophiles would inhabit a completely novel ecosystem where radioactive rocks are both the food and oxidant, rendering the system completely independent from oxygen. The potentially new ecosystem underneath the surface of the Earth could mimic subsurface rocks found on Mars, Europa, or elsewhere in the solar system (Li et al.).

Drawbacks

Astrobiology is not currently the main focus for extremophile research. Instead, much information is gathered about extremophiles for environmental or agricultural purposes. It is only afterwards or during analysis that applications to astrobiology is considered. Research that specifically connects extremophiles and space, such as the information on *X. elegans* conducted by Brandt et al. is needed. In addition, many extremophile research projects are connected to Martian environments, but not other types of environment, such as true space voids or other planets. To truly grasp the scope of extraterrestrial life, environments on other planets would need to be researched and compared for extremophile compatibility. Finally, extremophiles must be measured for survival rates over long period of times to truly understand if life on another planet is viable (Rampelotto).

Conclusion

Extremophile research is at the forefront of astrobiology, with many study applications connected to space research. This review covered the relationship between extremophiles on Earth and life on Mars. Even though extremophiles come from vastly diverse locations, such as in cold deserts, inside rocks, or in acidic environments, all have something to contribute to Martian research. By studying extremophiles on Earth, researchers better understand what type of life might exist on other planets. Future research will seek to test how other extremophiles survive in Martian conditions in similar conditions such as the *X. elegans* space experiment

(Brandt et al.). A promising organism to launch into space next would be some sort of psychrophiles living in the cold Antarctic deserts, like those discovered by Cockell and Stokes. There may even be life on Mars now, but current technology is not advanced enough to find it. The search for extraterrestrial life could lead to below the surface of the polar ice caps on Mars. The future of extremophile research will continue to push the boundaries of what was previously thought possible for life, whether that be on Earth or another planet.

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